A New Binary Inductive Divider Comparator System for Measuring High-Voltage Thermal Converters

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NIST
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Introduction

- Thermal voltage converters characterized by range-to-range build-up method
- Process requires small, stable voltage-level coefficients
- Voltage coefficients between 100 V and 1000 V can be significant compared to calibration uncertainties

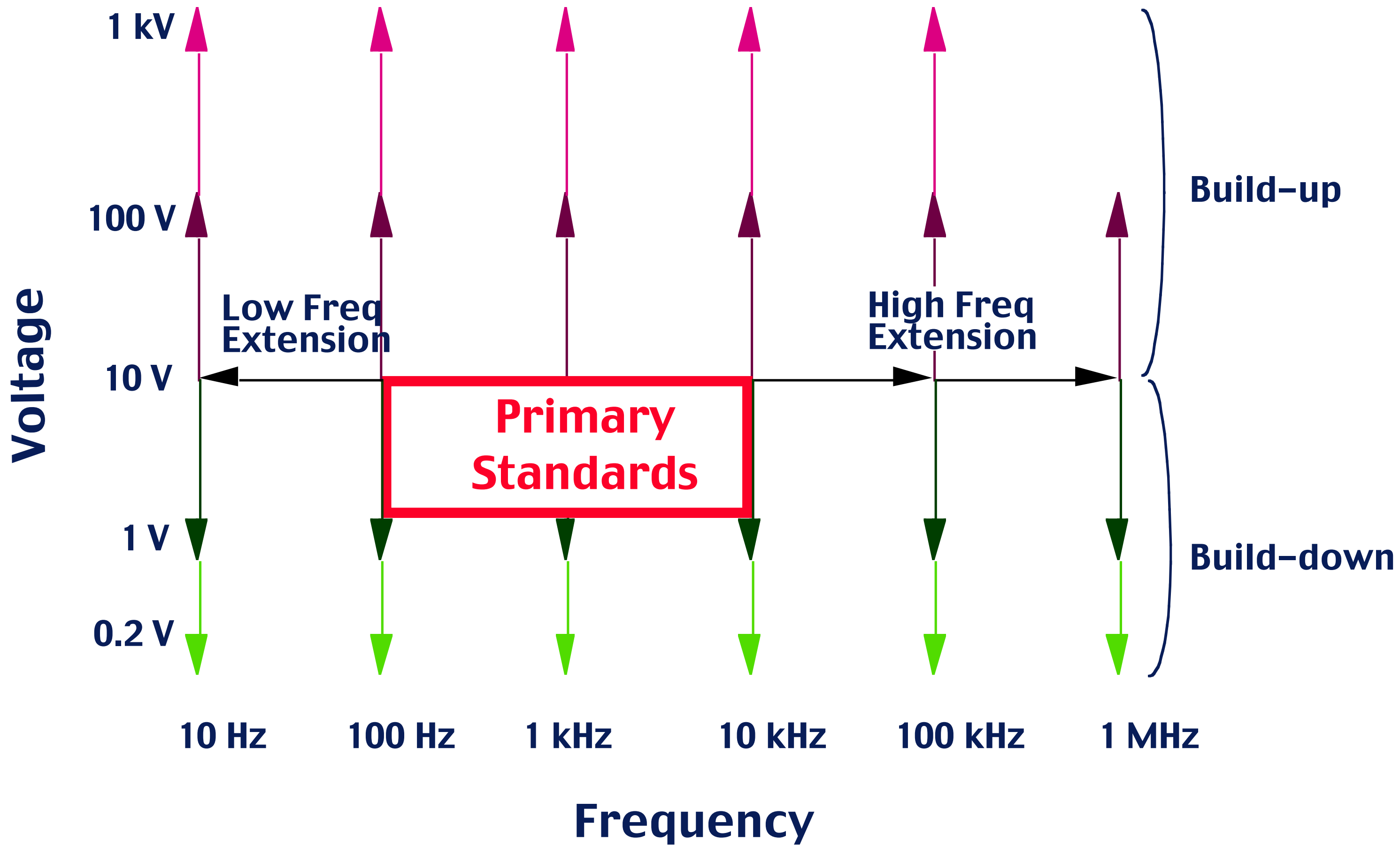


Diagram of the primary standards, high and low frequency extension paths and build-up and build-down paths.

- Formal and informal international intercomparisons have revealed variations among the participating laboratories
- Present work: compare the scaling accuracy of of the build-up process for HVTCs to a binary inductive voltage divider
- A completely independent principle

BIVD Comparator

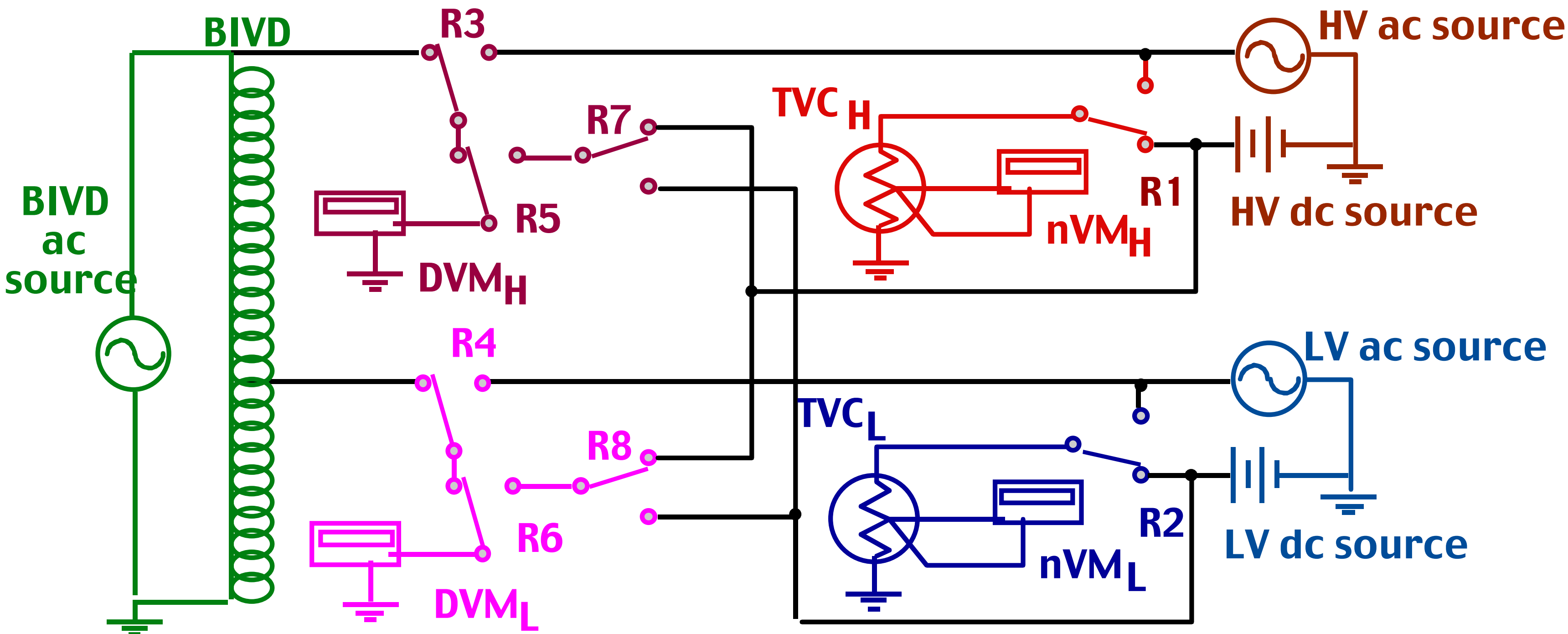
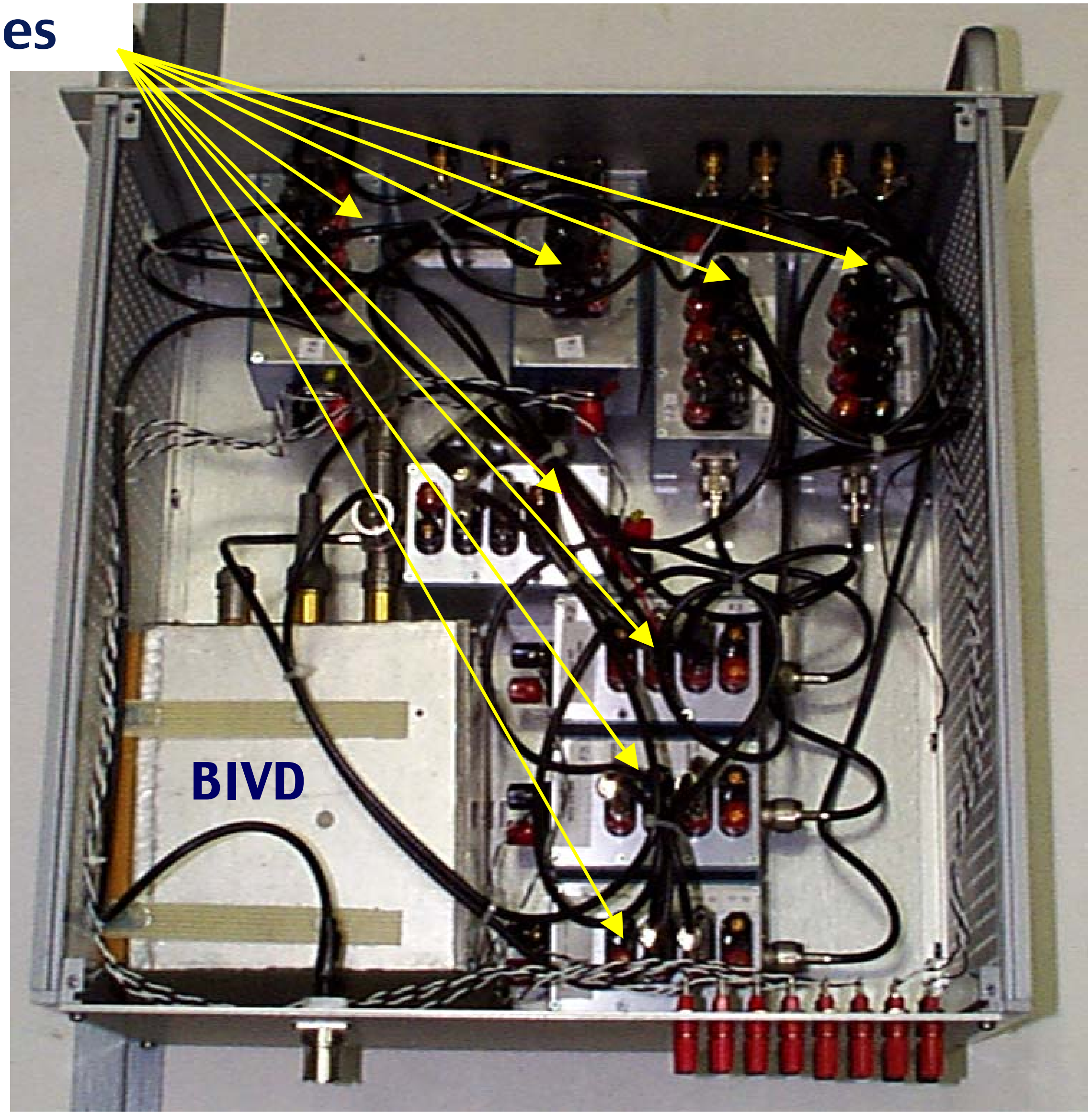


Diagram of automated BIVD system

Relay Modules



Interior view of BIVD comparator enclosure

BIVD Design

- **Components:**
  - Core: Supermalloy OD: 11.8 cm, ID: 7.6 cm, HT: 2.8 cm
  - Effective cross-sectional area : 4.2 cm^2
  - Wire: 20 AWG (0.52 mm^2), teflon insulation
  - Number of turns: 240

- Twisted pair connected to form a center tap
- Two layers of windings with a layer of a glass tape to reduce capacitance
- Winding technique provides good symmetry and well defined center tap

Testing of BIVD

- Center tap tested in a bridge configuration against a decade inductive voltage divider set at 0.5
- Bridge voltage source grounded and detector isolated by transformer
- Ratio error checked by inverting windings
- System checked against lower voltage ranges

Center Tap Error of BIVD (μV/V)

Frequency	Voltage 100 V	50 V
1 kHz	0.1	0.1
10 kHz	0.1	0.1
20 kHz	0.6	0.5

ANALYSIS

The relationships between the ac–dc differences of the TVCs and the ratios of the voltage sources is

$$\boxed{\delta_{meas} = \Delta ratio_{ac} - \Delta ratio_{dc} - d_{high} + d_{low}}$$

Where:

$$\boxed{\delta_{meas} = \delta_{high} - \delta_{low}}$$

δ_{high} **is ac–dc difference of** TVC_H

δ_{low} **is ac–dc difference of** TVC_L

$$\boxed{\frac{ac_H}{ac_L} = 2(1 + \Delta ratio_{ac})}$$

$\Delta ratio_{ac}$ **is the departure of the ac sources from nominal ratio as determined by the BIVD ratio**

$$\boxed{\frac{dc_H}{dc_L} = 2(1 + \Delta ratio_{dc})}$$

$\Delta ratio_{dc}$ **is the departure of the dc sources from nominal ratio as determined by the BIVD ratio**

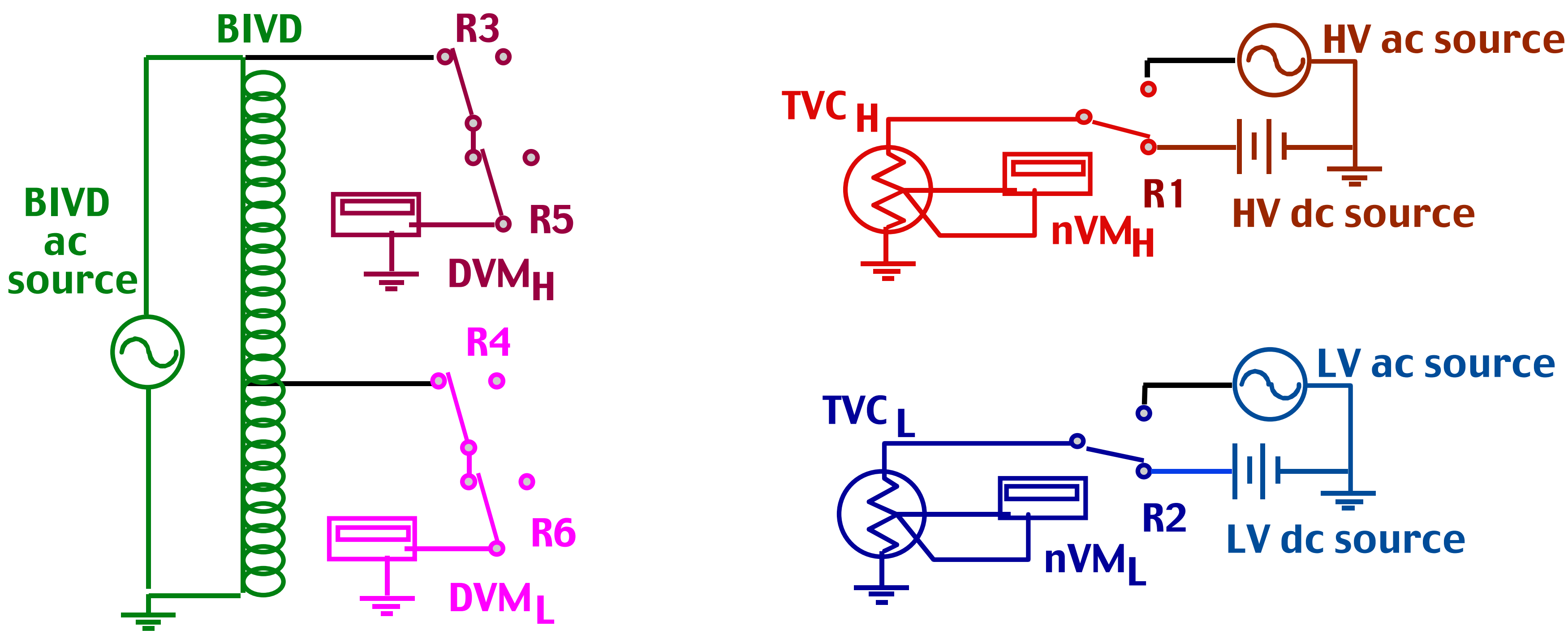
$$\boxed{d_{high} = \frac{E_{ac} - E_{dc}}{nE_{dc}}}$$

is the measured ac–dc difference of TVC_H

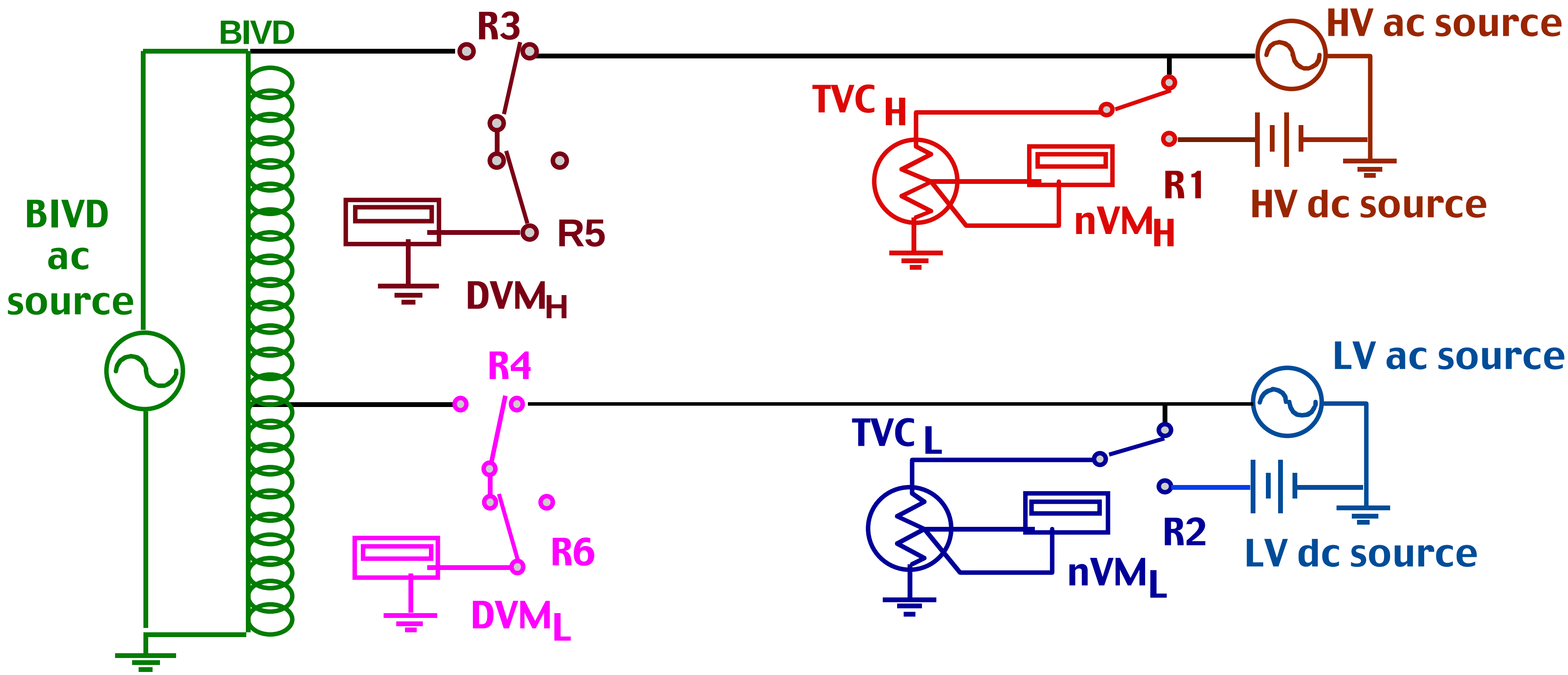
$$\boxed{d_{low} = \frac{E_{ac} - E_{dc}}{nE_{dc}}}$$

is the measured ac–dc difference of TVC_L

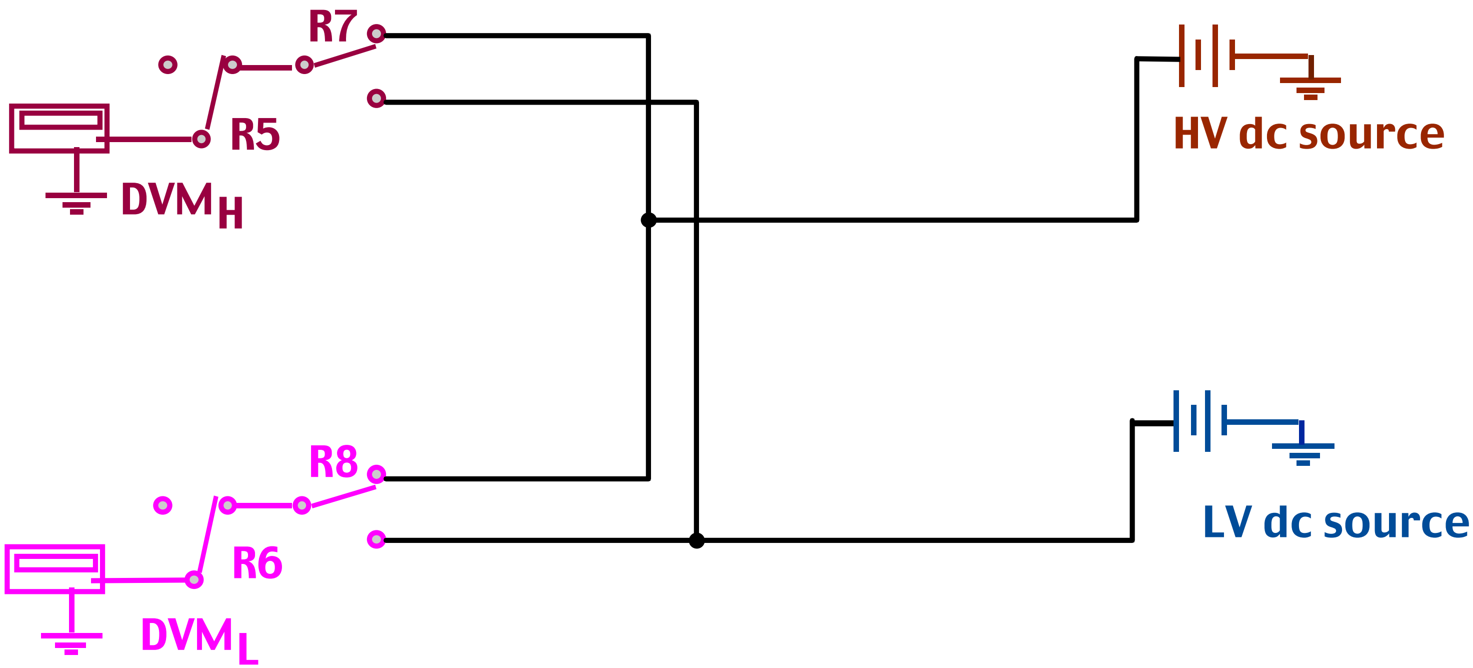
COMPARATOR OPERATION



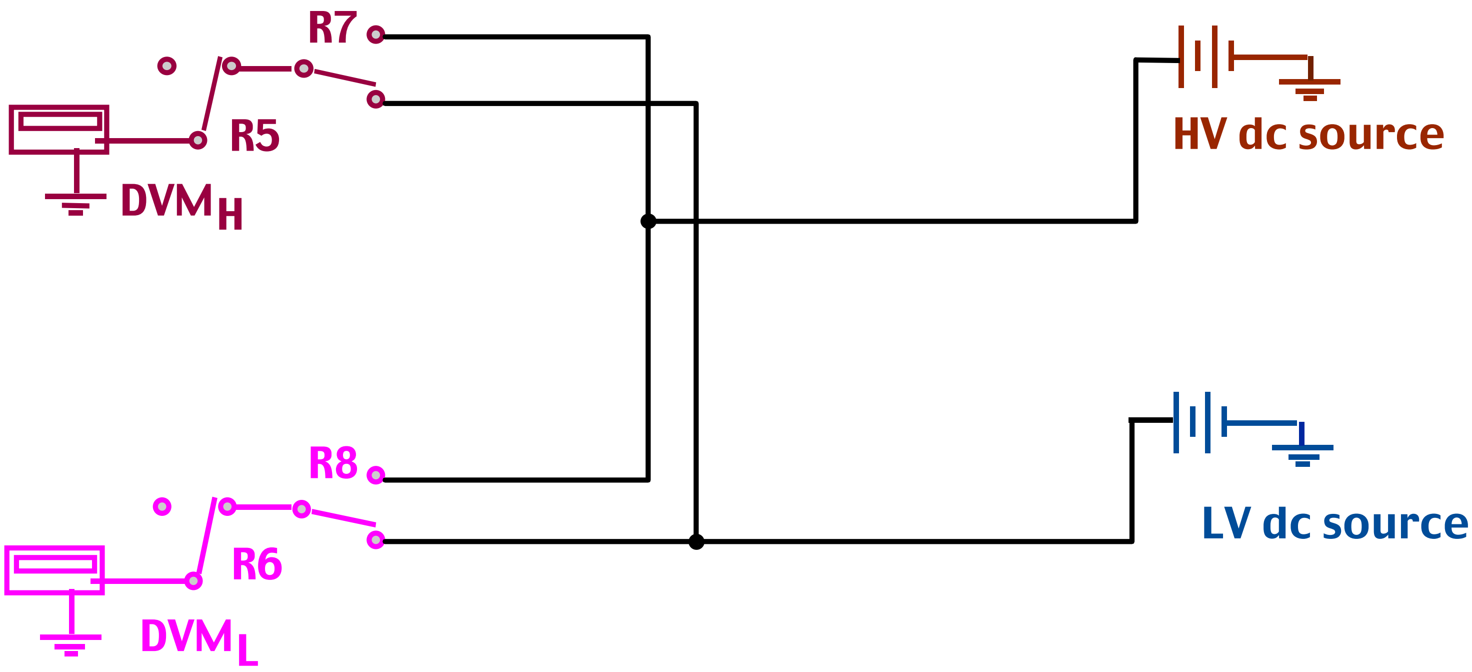
System configuration with dc applied to TVCs



System configuration with ac applied to TVCs



System configuration testing high voltage dc ratio



System configuration testing low voltage dc ratio

Loading Compensation

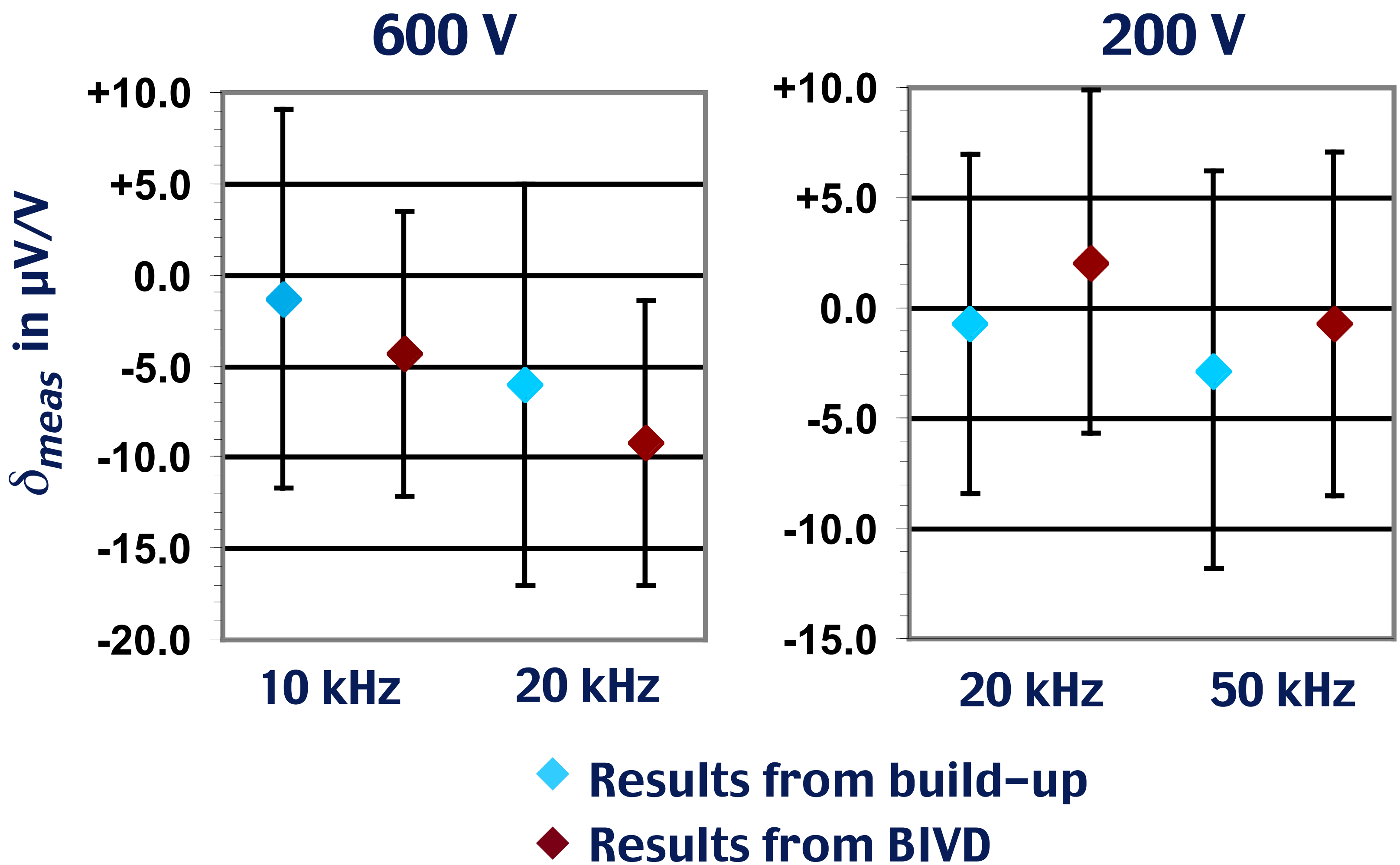
- Error of 10^{-4} in ratio at 20 kHz from loading at center tap
- Compensated by simple RC network with
  - R = 1 MΩ, C = 700 pF

  between BIVD high and center tap
- Error reduced to 10^{-6}
- Compensation is frequency dependent

BIVD UNCERTAINTIES

Type A Component	3.3
Dc Measurement	1.2
BIVD Ratio	1.2
Loading	1.2
RSS	3.9
Expanded Uncertainty (k = 2)	7.8

BIVD Results



Future Plans

- Extend applied voltage to 1000 V
- Fabricate BIVDs for different input frequencies
- Extend applied frequency
- Address sources of Type A uncertainties
- Use BIVD system for more extensive check of TVC build-up

Conclusions

- BIVD wound and characterized
- System incorporating BIVD assembled and tested up to 600 V
- Build-up process checked to 600 V
- BIVD system in good agreement with build-up to 600 V, 20 kHz